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Expansion of the southern limit of *Vampyrodes caraccioli* Thomas, 1889 (Chiroptera, Phyllostomidae) and first record for Santa Catarina state, southern Brazil

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Abstract
Three specimens of *Vampyrodes caraccioli* were collected in Corupá and São Bento do Sul, in Santa Catarina state, increasing its geographic distribution extension by 170 km south. These specimens also represent the first record for the species in Santa Catarina. The knowledge about bats in Santa Catarina has increased in recent years, showing the need of basic studies about richness and diversity in different regions.

Key words
Bats; Atlantic forest; geographic distribution; range extension; new record.

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Introduction

The knowledge about the bat fauna has increased in the last two decades in Brazil, with specialized publications about the group (Reis et al. 2007, Peracchi et al. 2012, Nogueira et al. 2014), description of new species (e.g. Gregorin and Ditchfield 2005, Miranda et al. 2006, Nogueira et al. 2012, Dias et al. 2013, Feijó et al. 2015, Moratelli and Dias 2015), and reports of new records for several regions (e.g. Zortéa et al. 2013, Dias et al. 2016, Basílio et al. 2017), including the southern region of the country (e.g. Weber et al. 2006, Gazarini and Bernardi 2007, Miranda et al. 2007, Scultori et al. 2009a, b, c, Carvalho and Fabián 2011, Carvalho et al. in press). Additionally, in the last 6 years the distribution of the genus *Vampyrodes* Thomas, 1900 has been expanded (Velazco et al. 2010, Velazco and Simmons 2011, Carvalho et al. 2014, Lopes et al. 2016).

Vampyrodes was considered for a long time as a monotypic genus (Gardner 2008a, Velazco et al. 2010), however, it is currently composed of 2 species: *Vampyrodes major* Allen, 1908 and *Vampyrodes caraccioli* (Thomas, 1889), both species overlapping in their areas of distribution in the northern part of South America, more specifically in Colombia (Velazco and Simmons 2011). Considering the variation on body size observed within the family Phyllostomidae, both species are considered as medium-sized bats, with forearm length ranging between

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46.8 mm to 57.3 mm and weight from 25 g to 34 g (Willis et al. 1990, Gardner 2008a, Zortéa 2007), *V. caraccioli* being smaller than *V. major* (Velazco and Simmons 2011). The genus shows 4 facial stripes well pronounced and 1 on the dorsal region, extending from the top of the head until the uropatagium base (Zortéa 2007, Peracchi et al. 2012). Despite the similarities, the species are easily distinguished by external morphological characters, such as the length of dorsal pelage, uropatagium edge shape, and number and position of vibrissae (Velazco and Simmons 2011, Díaz et al. 2016).

Vampyrodes caraccioli is distributed in South America, with confirmed records for Colombia, Ecuador, Bolivia, Trinidad, Tobago, Venezuela, French Guiana, Suriname, Guyana, and Brazil (Velazco and Simmons 2011). In Brazil, the species has been reported to occur in Acre, Amazonas, Amapá, Bahia, Mato Grosso, Mato Grosso do Sul, Pará, Rio de Janeiro, São Paulo, and Paraná (Lopes et al. 2016), the last state considered the known austral limit of the species distribution (Carvalho et al. 2014). *Vampyrodes. caraccioli* is usually reported with small abundance in inventories (e.g Kalko and Handley 2001, Martins et al. 2006, 2011, Souza et al. 2015), compromising further information about its biology and ecology. The present note aims to report the expansion of the Southern limit distribution of *Vampyrodes caraccioli* and the first record for Santa Catarina state in southern Brazil.

Methods

The records here reported were obtained during samplings of bats in 2 areas in the north of Santa Catarina state, Brazil. Area I corresponds to the Reserva Particular do Patrimônio Natural Emílio Fiorentino Batistela, in Corupá (26°25′45″ S, 049°′48″ W, Datum SAD 69, Fig. 1). The Reserva is located on the hillsides of the Serra Geral, and the altitude of the sampling area averages 265 m above sea level. Area II corresponds to the surroundings of the Centro de Estudos e Pesquisas Ambientais (CEPA) Rugendas, belonging to the Universidade Regional de Joinville, São Bento do Sul (26°03′00″ S, 049°03′00″ W, Datum SAD 69, Fig. 1), average elevation of this area is 800 m above sea level. According to phytogeographic classification, both areas are inserted within the Atlantic Forest Biome, area I is located on submontane ombrophilous dense forest and area II is located on montane ombrophilous dense forest (IBGE 2012). Based on the Köppen classification, the climate in both areas is Cfa-type, humid subtropical climate without dry season set (Alvares et al. 2013).

Seventeen morphological measurements were obtained from specimens using a digital calipter: FA = forearm size, GLS = total length of skull, CIL = condyle incisive length, CCL = condyle canine length, BB = width of the braincase, ZB = zygomatic width, PB = Postorbital breadth, C-C = Palatal width at canines, PL = Palatal length, MTRL= Length of the series of teeth of the maxilla, MLTRL = Length of the molars, M1-M1 = Width between M1, M2-M2 = Width between M2, MB = Mastoid width, COH = Coronoid height, DENL = Tooth length, and MANDL = Length of series of teeth of the mandible (Table 1). All measurements are presented in millimeters and follow Velazco and Simmons (2011). Voucher specimens were prepared and deposited in the Coleção Zoológica da Universidade Regional de Blumenau (CZFURB). The authorization for performing the studies was issued by SISBIO under the number 26934-1. All procedures being performed according to protocols of the American Society of Mastozoology for the use of mammals in research (Sikes et al. 2011).

Results

Three individuals of *Vampyrodes caraccioli* were captured in the northern region of Santa Catarina. One female caught on 23 August 2012 (SLA3481, Fig. 2) and 1 male caught on 11 November 2012 (SLA3796) were captured in area I. The specimen captured in area II was a female caught on 27 June 2015 (SLA5623).

The identification of the collected specimens was made using the key provided by Lim and Engstron (2001), Gardner (2008a), Velazco and Simmons (2011), and Díaz et al. (2016). The identification of the specimens at the genus level was based on the following characteristics: (1) presence of facial and dorsal stripes, (2) dorsal list starting at the top of the head, extending to the base of the uropatagium, (3) edge of uropatagium with fringe of hairs, (4) incisors upper 2/2, (5) incisors upper no bilobates, (6) central superior incisors, twice as large as the lateral incisors, (7) molars 2/3, and (8) second molar superior equal to or smaller in size when compared to the first molar. Identification at the species level was based on the observation of the following characters: (1) metacarpal III longer than metacarpal V, (2) U-inverted shape on the posterior edge of the uropatagium, (3) dense and short fur (< 2 mm) on the edge of the uropatagium, (4) parietal foramen well separated from the nuchal crest, (5) presence of little developed groove between the occipital condyle and the paracondylar process, (6) paroccipital process well developed, (7) I1 well developed and bilobed, (8) inferior incisors robust and bilobed, and (9) accessory lingual cusp in p4.

Discussion

The records reported here extend the distribution of *V. caraccioli* by 170 km, making it the new limit of the southern distribution for this species. This species has been recorded for the Atlantic Forest biome in the northeast (Faria 2006), southeast (Lourenço et al. 2010, Velazco et al. 2010, Souza et al. 2015) and recently in the south region of Brazil, in Paraná state, with this being the austral limit known for this species (Carvalho et al. 2014). Studies about the fauna of bats for the state of Santa Catarina had not listed *V. caraccioli* (Cherem et al. 2004, Passos et al. 2010) and this study also represents the

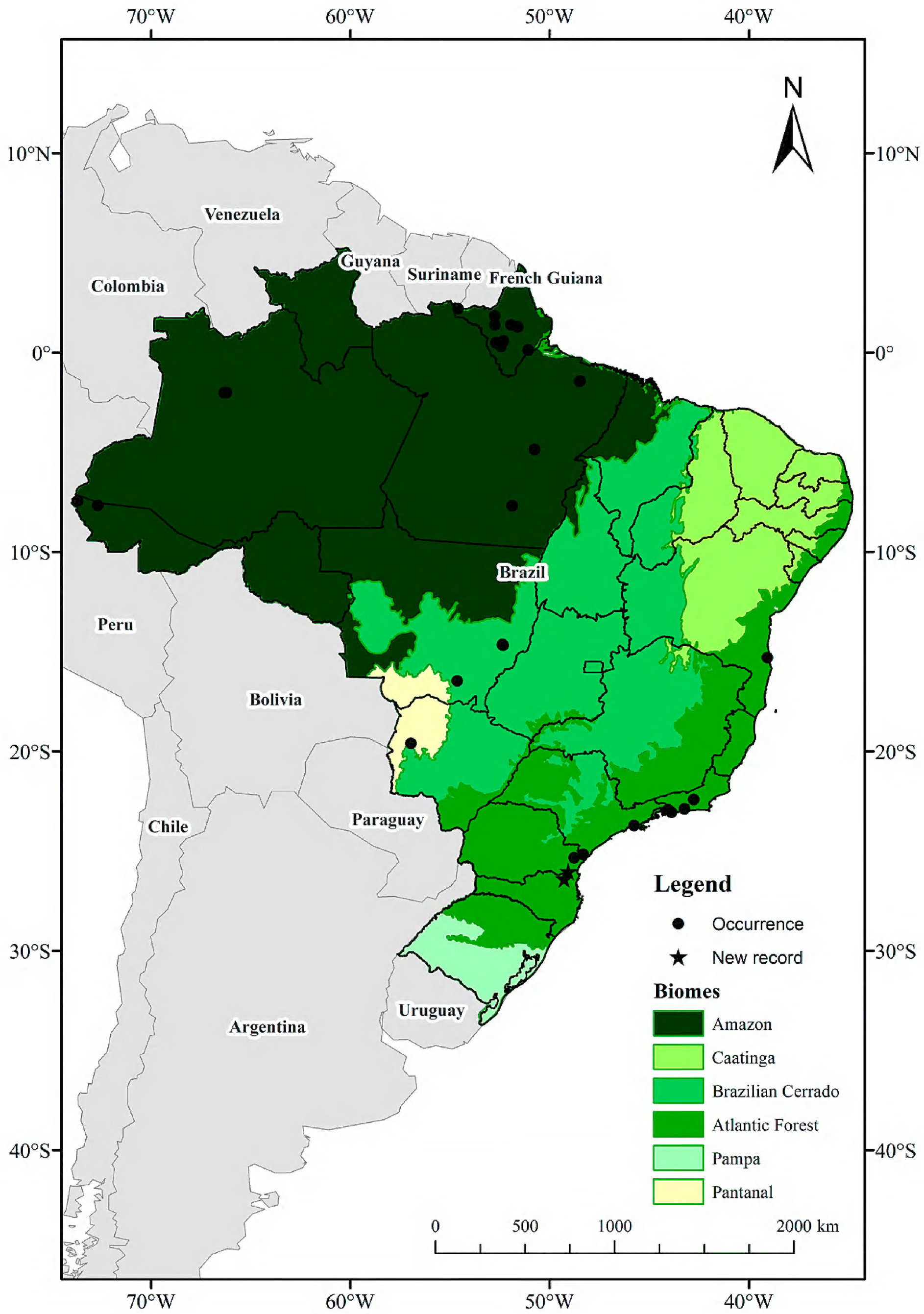

Figure 1. Distribution of *Vampyrodes caraccioli* records in Brazil reported by Lopes et al. (2016) (dot) and new occurrence records of the species in northern Santa Catarina state, south of Brazil (star).

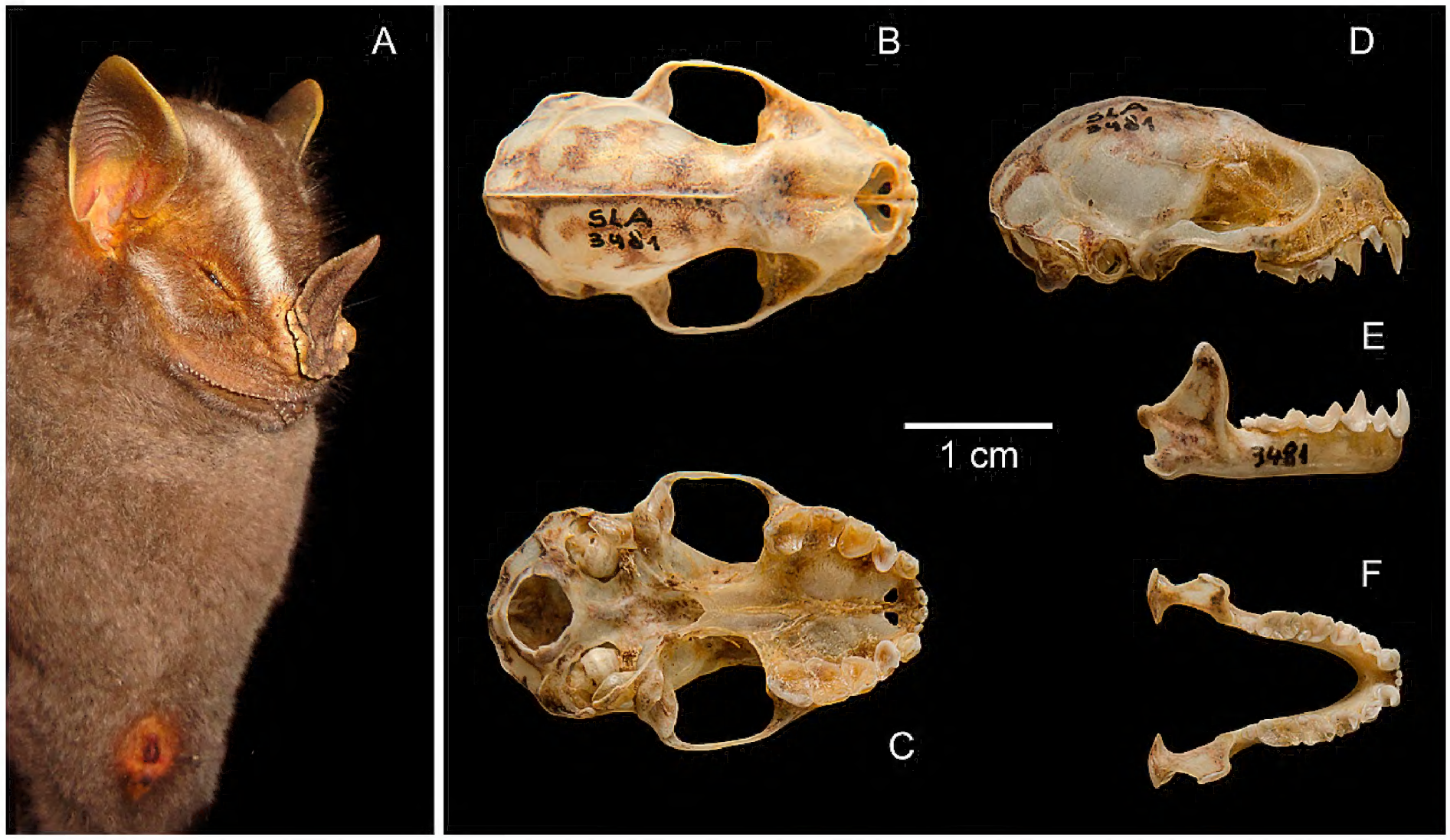

Figure 2. A. Specimen of *Vampyrodes caraccioli* (SLA 3481♀), captured in city of Corupá, in north Santa Catarina state. **B–F.** Dorsal (B), ventral (C), and lateral views of the skull (D) and dorsal (E) and lateral (F) views of the mandible.

first record of this species in the state of Santa Catarina.

Considering the new record of *V. caraccioli* for Santa Catarina, the number of bats species occurring in this state has increased to 50 species (Passos et al. 2010, Carvalho et al. 2011, Cherem and Althoff 2016, Carvalho et al. in press). At least 117 species have been registered to the Atlantic Forest bioma (Varzinczak et al. 2015), 42.7% of them being recorded in Santa Catarina, turning the state into a hot spot for bat diversity in Brazil. Bats in Santa Catarina belong mainly to Phyllostomidae (19 spp.) and Vespertilionidae (14 spp.) (Passos et al. 2010), which differs from other regions of Brazil, in which Phyllostomidae represents more than 50% of the total registered species (e.g. Esbérard 2003, Bernard and Fenton 2007, Alho et al. 2011, Carvalho et al. 2013, Felix et al. 2016). The typical temperate climate in the southern region of Brazil can limit the occurrence of tropical bat species, specifically in the southern portion of the Atlantic Forest (Fabián et al. 1999), where at least 24 species of Phyllostomidae have their southern limits of distribution (e.g. Gardner 2008b).

Among the 17 morphological measurements obtained from the 3 specimens reported here, values obtained for 14 of them were above the variation range described in the literature for *Vampyrodes caraccioli* (Velazco et al. 2010, Velazco and Simmons 2011). These data reinforce the hypothesis of clinal variation occurrence for this species (Carvalho et al. 2014), although the confirmation of clinal variation is only possible through the analysis of many individuals (Scultori et al. 2009c). Even though the area-volume relation is used to explain the increase in body size of several taxa of mammals in areas of high latitude, factors such as availability and size of food resources can also influence in this relation (see McNab 1971). In Chiroptera, variation in body size between populations of different latitudes has been observed for several species (e.g Tavares and Velazco 2010, Garbino 2011, Moratelli and Oliveira 2011). For almost all measurements, females were larger than males, which could be an indicative of sexual dimorphism for the specimens collected in this study, although Velazco and Simmons (2011) did not observe this dimorphism when a larger number of specimens was analyzed.

The last decades have experienced an increase on the number of published studies about biology and ecology of bats, especially in the North and South of Santa Catarina (e.g. Carvalho et al. 2008, 2009a, b, Cherem et al. 2011, Carvalho et al. 2013). On the other hand, in the west of Santa Catarina few studies have been carried out on the fauna of bats (e.g. Miranda et al. 2007, Cherem and Althoff 2016), even though it is one of the priority regions for studies on the fauna of bats in the state of Santa Catarina. For the Atlantic Forest Domain, the fauna of bats can still be subsampled even in areas with a large sampling effort (Varzinczak et al. 2015). Studies on the composition of the assemblages are still of fundamental importance. Information resulting from these are important for conservation action plans, in addition to aiding in determining the conservation status of the species and its biology.

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Table 1. Morphological measures of *Vampyrodes caraccioli* available in literature and of the 3 specimens captured in the northern region of Santa Catarina, southern Brazil. All measurements are presented in millimeters (mm).

Character	Velazco et al. (2010)		Velazco and Simmons (2011)		Carvalho et al. (2014)	Present study		
	Holotypes	(*N* = 1)	(*N* = 55)		(*N* = 1)	(*N* = 3)		
		♀	♀	♂	♂	♀SLA3481	♀SLA3796	♂SLA5623
FA	49.70	54.03	47.28–55.98	48.79–53.96	53.9	55.9	56.0	53.3
GLS	—	28.3	25.22–27.97	24.14–27.56	29.1	29.11	29.48	28.89
CIL	—	25.83	22.54–25.40	22.99–25.34	25.1	26.03	26.35	25.69
CCL	—	25.17	21.98–24.98	22.58–24.66	24.6	25.35	25.72	25.01
BB	—	10.98	10.88–11.91	10.90–11.94	11.9	11.90	11.99	11.82
ZB	—	17.79	15.92–17.89	15.76–17.62	18.3	18.53	18.80	17.93
PB	6.10	6.55	5.87–6.79	5.99–6.69	6.2	6.72	6.83	6.56
C-C	6.30	6.7	6.13–7.08	6.26–6.96	6.9	7.36	7.43	7.19
PL	12.45	14.14	12.25–14.39	12.99–14.46	13.1	14.04	14.14	14.05
MTRL	9.50	10.37	9.23–10.25	9.34–9.94	10	10.16	10.62	10.07
MLTRL	7.85	8.88	7.71–8.77	7.55–8.43	8.3	8.61	8.71	8.54
M1-M1	11.00	12.26	10.78–12.28	10.64–12.22	12.5	12.92	13.23	12.69
M2-M2	11.20	12.71	11.23–12.37	11.17–12.37	12.8	13.44	13.70	12.96
MB	—	—	11.78–13.24	11.57–12.80	12.9	13.30	13.39	13.09
COH	—	—	7.13–8.28	7.28–8.23	8.6	9.08	9.23	8.91
DENL	17.35	19.32	16.91–19.10	17.12–19.07	19.1	19.45	19.76	18.82
MANDL	10.50	11.45	10.04–11.27	10.06–11.27	11.1	11.58	11.68	11.22

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Authors' Contributions

BT, MARF, MJR and SLA collected the data and did the analysis; BT, FC and SLA wrote the text and did the analysis.

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